

PATENT SPECIFICATION (11)

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- (21) Application No. 16301/75 (22) Filed 21 April 1975 (19)
 (31) Convention Application No. 462 796 (32) Filed 22 April 1974 in
 (33) United States of America (US)
 (44) Complete Specification published 21 Dec. 1977
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(54) IMPROVEMENTS IN OR RELATING TO MATERIAL HANDLING VEHICLES

- (71) We, EATON CORPORATION, a corporation organised and existing under the laws of the State of Ohio, United States of America, of 100 Erieview Plaza, Cleveland, Ohio 44114, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates generally to vehicles and concerns load moving vehicles including means for preventing the application of excessive overturning moments to the vehicles.
- Lift trucks are commonly provided with upstanding masts which are movable relative to the vehicle by a tilt motor. Upon operation of the tilt motor, the mast is moved between an upright position and a forwardly or rearwardly canted or tilted position. In addition, a lift or hoist motor is effective to move a load engaging fork or platform vertically along the mast to raise and lower a load relative to the vehicle.
- During operation of the tilt motor to move the mast to a forwardly tilted position means in such a manner that the load subjects the vehicle to an increasing moment which tends to overturn the vehicle, variable displacement pump means for supplying fluid to said motor means, actuator means for varying the displacement of said pump means, and detector means for detecting the overturning moment to which the vehicle is subjected and for effecting operation of said actuator means to reduce the displacement of said pump means in response to the detection of an overturning moment of a value in excess of a predetermined overturning moment.
- Said support means may include an upstanding mast and a load engaging carriage connected with said mast, said motor means including a tilt motor connected with said mast and operable to change the angle of inclination of said mast relative to a vehicle support surface, said detector means being operable to detect the overturning moment applied to said vehicle as a result of operation of said tilt motor.
- The tilt motor may include a cylinder defining a chamber and a piston disposed

PATENTS ACT 1949

SPECIFICATION NO 1495675

Amendment is made in accordance with the Decision of the Principal Examiner acting for the Comptroller-General, dated the 17th day of April 1978 under Section 9 in the following manner:-

Reference has been directed in pursuance of Section 9 subsection (1) of the Patents Act 1949 to Patent No 1461914

THE PATENT OFFICE
17 May 1978

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for use in moving a load, said vehicle comprising support means for supporting a load. fluid motor means for moving said support actuator means to reduce the displacement of said pump means in response to detection of a fluid pressure output which is greater

SPECIFICATION AMENDED - SEE ATTACHED SHEET

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(71) We, EATON CORPORATION, a corporation organised and existing under the laws of the State of Ohio, United States of America, of 100 Erieview Plaza, Cleveland, Ohio 44114, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to vehicles and concerns load moving vehicles including means for preventing the application of excessive overturning moments to the vehicles.

Lift trucks are commonly provided with upstanding masts which are movable relative to the vehicle by a tilt motor. Upon operation of the tilt motor, the mast is moved between an upright position and a forwardly or rearwardly canted or tilted position. In addition, a lift or hoist motor is effective to move a load engaging fork or platform vertically along the mast to raise and lower a load relative to the vehicle.

During operation of the tilt motor to move the mast to a forwardly tilted position, a center of gravity of a load engaged by the fork is moved forwardly so that the load is effective to apply an increasing overturning moment to the vehicle. In addition, the overturning moment applied by the load to the vehicle increases as the lift motor moves the load upwardly along the tilted mast. Of course, if the overturning moment applied by the load to the vehicle becomes excessively large, the vehicle will be tipped or turned over. It has been previously suggested to prevent the application of excessive overturning moments to the vehicle by hydraulically locking the tilt and lift motor assemblies upon the application of a predetermined overturning moment to the vehicle in the manner disclosed in the U.S. Patent No. 3,007,593.

The present invention provides a vehicle for use in moving a load, said vehicle comprising support means for supporting a load, fluid motor means for moving said support

means in such a manner that the load subjects the vehicle to an increasing moment which tends to overturn the vehicle, variable displacement pump means for supplying fluid to said motor means, actuator means for varying the displacement of said pump means, and detector means for detecting the overturning moment to which the vehicle is subjected and for effecting operation of said actuator means to reduce the displacement of said pump means in response to the detection of an overturning moment of a value in excess of a predetermined overturning moment.

Said support means may include an upstanding mast and a load engaging carriage connected with said mast, said motor means including a tilt motor connected with said mast and operable to change the angle of inclination of said mast relative to a vehicle support surface, said detector means being operable to detect the overturning moment applied to said vehicle as a result of operation of said tilt motor.

The tilt motor may include a cylinder defining a chamber and a piston disposed within said chamber, said piston being effective to divide said chamber into first and second end portions, and said detector means may include means for comparing the fluid pressure in one of said end portions of said chamber relative to the fluid pressure in the other of said end portions of said chamber to thereby detect the overturning moment applied to the vehicle.

Valve means may be included operable between a first condition blocking fluid flow from said pump means to said motor means and a second condition enabling fluid to flow from said pump means to said motor means, and compensator means for detecting when the fluid pressure output of said pump means is greater than a predetermined pressure when said valve means is in said first condition and for effecting operation of said actuator means to reduce the displacement of said pump means in response to detection of a fluid pressure output which is greater

than the predetermined pressure when said valve means is in said first condition.

More specifically, the present invention provides a vehicle comprising a base, an up-
 5 standing mast connected with said base, load engaging means connected with said mast for engaging a load, tilt motor means for moving said mast and load engaging means relative to said base in such a manner as to
 10 vary an overturning moment to which said vehicle is subjected by a load engaged by said load engaging means, said tilt motor means including a piston and cylinder defining first and second chamber end portions,
 15 variable displacement pump means for supplying fluid under pressure to said cylinder of said motor means, said tilt motor means including means for subjecting fluid in one of said chamber end portions to forces which
 20 vary as a function of the overturning moment to which the vehicle is subjected and as a function of the fluid pressure in the other chamber end portion, actuator means operable to vary the displacement of said pump
 25 means, and comparator means for comparing the fluid pressures in said first and second chamber end portions and effecting operation of said actuator means to reduce the displacement of said pump means when
 30 the fluid pressure in said one chamber end portion exceeds the fluid pressure in said other chamber end portion by a predetermined amount.

The foregoing and further optional
 35 features of the present invention will become more apparent upon a consideration of the following description, given by way of example and not by way of limitation, with reference to the accompanying drawings wherein:

Fig. 1 is a schematic illustration of a material handling vehicle having a mast which is movable by a tilt motor and a load
 45 engaging fork or platform which is movable vertically along the mast by a lift motor;

Fig. 2 is a partially broken away schematic illustration, generally similar to Fig. 1, illustrating the mast in a forwardly tilted
 50 position;

Fig. 3 is a schematic illustration depicting the relationship between the tilt motor, the lift motor, a variable displacement pump, and a detector assembly which effects a reduction in the displacement of the pump
 55 upon the application of a predetermined overturning moment to the vehicle of Fig. 1; and,

Fig. 4 is a schematic illustration for a second embodiment of the invention.

60 With reference to the accompanying drawings, a material handling vehicle or lift truck 10 constructed in accordance with the present invention is illustrated in Fig. 1 and includes an upstanding mast 12 upon which
 65 a load engaging platform or fork 14 is moun-

ted. A lift or hoist motor 18 (Fig. 2) is operable to raise and lower the lift fork 14 and load disposed thereon. A tilt motor assembly 22 is operable between the retracted condition of Fig. 1 and the extended
 70 condition of Fig. 2 to pivot the mast 12 about a connection 24 between the mast and the frame of the vehicle.

It should be noted that for the sake of clarity and consistency the vertical condition of Fig. 1 has been defined as representing the retracted condition of the mast 12. In use, the retracted position for the mast may also be an inclination which is disposed rearwardly from the vertical. From such a
 75 position, an overload may occur prior to the mast reaching vertical. Of course, the principles and solutions of this invention apply equally well to the latter case, as will be readily recognized by those of ordinary skill in the art. Thus, while the position of Fig. 1
 80 will hereafter be referred to as the retracted position, it should be apparent that the present invention contemplates, and functions properly with, a retracted position which is disposed rearwardly from the vertical.
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Operation of the tilt motor assembly 22 is controlled by a valve 28. Upon actuation of the tilt motor control valve 28 from the closed position of Fig. 3 to a forward actuated position, a fluid passage 30 in the valve 28 is effective to port fluid from a variable displacement pump 32 to the tilt motor assembly 22. This fluid effects operation of the tilt motor 22 to move the mast 12 from the upright position shown in Fig. 1 to the tilted position of Fig. 2. Similarly, upon operation of the tilt control valve 28 to a reversed actuated position, a second passage 34 in the valve 28 is effective to port fluid from the pump 32 to the tilt motor assembly 22 to effect operation of the tilt motor assembly from the extended condition of Fig. 2 to the retracted condition of Fig. 1.
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A lift motor control valve 38 is actuable to effect operation of the lift motor 18 to raise or lower a load on the lift fork 14. Thus, upon operation of the control valve 38 toward the right (as viewed in Fig. 3) fluid from the pump 32 is ported through a passage 42 to the head end of the lift motor 18 to extend the lift motor 18 and raise a load on the fork 14. Similarly, upon operation of the control valve 38 toward the left (as viewed in Fig. 3) a passage 44 is effective to port the head end of the lift motor 18 to drain so that the weight of the lift fork 14 and any load thereon causes the lift motor 18 to be retracted. Although the lift motor 18 is of the single acting type, a double acting lift motor could be utilized if desired.
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Assuming that there is a load on the lift fork 14, when the tilt motor 22 is operated from the retracted condition of Fig. 1 to the
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extended condition of Fig. 2 to tilt the mast 12, the center of gravity of the load engaged by the lift fork 14 is shifted outwardly from the front wheels 48 of the lift truck. This outward shifting of the centre of gravity of the load increases the overturning moment which is applied to the vehicle 10. Similarly, if the lift motor 18 is extended to raise the lift fork 14 with the mast 12 in the tilted position of Fig. 2, the center of gravity of the load is moved outwardly to further increase the overturning moment to which the vehicle 10 is subjected. If this overturning moment is allowed to become excessive, the vehicle could be tipped or overturned, that is rotated in a clockwise direction about the wheels 48 of the vehicle. Of course overturning of the vehicle 10 could cause severe injuries to an operator of the vehicle.

The application of excessive overturning moments to the vehicle 10 is prevented by reducing the effective displacement of the pump 32 upon the application of an overturning moment of the vehicle which is in excess of a predetermined permissible overturning moment. To this end, a detector assembly 50 is operable to sense variations in the overturning moment applied to the vehicle and to initiate movement of an actuator member 52 when the predetermined overturning moment is exceeded. Movement of the actuator member 52 reduces the displacement of the pump 32 so that it is ineffective to supply fluid, that is there is no fluid flow from the pump 32 and it has substantially zero effective displacement.

If the pump 32 is of the swashplate type, movement of the actuator member 52 could be utilized to actuate a valve to effect operation of a suitable motor to vary the relative positions of the swashplate and cylinders of the pump in a manner similar to that disclosed in U. S. Patent No. 3,528,243. Similarly, movement of the actuator member 52 can be utilized to move a control or cam ring to decrease the displacement of a pump in the manner disclosed in U. S. Patent No. 3,376,703. Regardless of what known control apparatus is utilized to reduce the effective displacement of the pump 32 in response to movement of the actuator member 52, it should be understood that the actuator member 52 is moved toward the right (as viewed in Fig. 3) to effect a reduction in the effective displacement of the pump 32 and is moved toward the left, under the influence of a biasing spring (not shown) to effect an increase in the effective displacement of the pump.

The detector assembly 50 compares the fluid pressure in rod end chambers 54 and 56 of the tilt motor assembly 22 with the fluid pressure in head end chambers 58 and 60 of the tilt motor assembly. The pressure in the rod end chambers 54 and 56 of the

tilt motor assembly 22 varies as a function of the fluid pressure in the head end chambers 58 and 60 and as a function of the overturning moment applied to the vehicle 10. Thus, pistons 64 and 66 are pressed toward the right (as viewed in Fig. 3) under the influence of fluid pressure in the chambers 58 and 60. In addition, the pistons are pulled toward the right (as viewed in Fig. 3) by forces transmitted from the mast 12 through piston rods 68 and 70. As the overturning moment applied to the mast 12 increases, the force tending to pull the piston rods 68 and 70 toward the right (as viewed in Fig. 3) increases. Therefore, the pressure applied to the fluid in the chambers 54 and 56 varies as a function of both the fluid pressure in the chambers 58 and 60 and the overturning moment applied to the vehicle 10.

The fluid pressure in the rod end chambers 54 and 56 of the tilt motor 22 is increased in response to an increase in the overturning moment applied to the vehicle 10 due to either a tilting of the mast 12 or operation of the lift motor 18 to raise a load then the mast is in a tilted condition. Thus, when the mast is tilted, the overturning moment applied to the vehicle 10 by a given load varies as a function of the horizontal component of the position vector describing the location of the center of gravity of the load. Thus, as the mast 12 is tilted forwardly the clockwise (as viewed in Fig. 2) overturning moment applied to the mast increases. Similarly, when the lift motor 18 is extended to raise the load with the mast in the tilted condition of Fig. 2, the center of gravity of the load moves both upwardly and outwardly away from the pivot connection 24. This results in an increase in the clockwise (as viewed in Fig. 2) overturning moment applied to the mast 12.

The tilt motor assembly 22 applies a counterclockwise (as viewed in Fig. 2) moment to the mast 12 to offset the clockwise overturning moment. However, the tilt motor assembly 22 applies the offsetting moment through a fixed lever arm determined by the distance between the pivot connection 24 and the connections between the mast 12 and the tilt motor assembly 22. Therefore, when the clockwise (as viewed in Fig. 2) overturning moment applied to the mast 12 increases due to either a forward tilting of the mast or the raising of the load, the counterclockwise offsetting moment applied to the mast can be increased only by increasing the force transmitted to the mast from the tilt motor 22 through the piston rods 68 and 70. Therefore, the rightward (as viewed in Figs. 2 and 3) force on the piston rods 68 and 70 varies as a substantially linear function of the overturning moment applied to the vehicle by the load. 130

This results in a linear variation of the pressure in the rod end chambers 54 and 56 with variations in overturning moment.

When the fluid pressure in the rod end chambers 54 and 56 exceeds the fluid pressure in the chambers 58 and 60 by a predetermined amount, a predetermined overturning moment will have been applied to the vehicle 10. The detector assembly 50 continuously compares the fluid pressure in the rod end chambers 54 and 56 of the tilt motor 22 with the fluid pressure in the head end chambers 58 and 60 to determine when the predetermined overturning moment has been applied to the vehicle 10. Thus, the detector assembly 50 includes a fixed cylinder 72 which cooperates with a movable piston 74 to define a pair of pressure chambers 76 and 78. The pressure chamber 76 is connected in fluid communication with the rod end chambers 54 and 56 of the tilt motor 22 through a conduit 82. Similarly, the pressure chamber 78 is connected with the head end chambers 58 and 60 of the tilt motor 22 through a conduit 84.

When the fluid pressure in the chamber 76 exceeds the fluid pressure in the chamber 78 by a predetermined amount due to the application of a relatively large overturning moment to the vehicle 10, the piston 74 is moved toward the right (as viewed in Fig. 3) against the influence of a biasing spring 88. This movement of the piston 74 causes the actuator member 52 to move toward the right to thereby effect a reduction in the displacement of the pump 32 to a zero flow condition. It should be noted that the biasing spring 88 prevents rightward movement of the piston 74 until immediately after a predetermined maximum permissible overturning moment is applied to the vehicle 10. When the overturning moment applied to the vehicle 10 is reduced, the spring 88 moves the piston 74 toward the left (as viewed in Fig. 3) relative to the fixed cylinder 72. As this occurs, the actuator member 52 also moves toward the left (as viewed in Fig. 3) and the displacement of the pump 32 is increased.

The detector assembly 50 compares the fluid pressure in the rod end chambers 54 and 56 to the fluid pressure in the head end chambers 58 and 60. To provide for a direct comparison the ratio of the surface areas of the piston 74 is the same as the ratio of the surface areas of the pistons 64 and 66. Thus, the ratio of the surface area 94 of the piston 74 to the surface area 96 of the piston 74 is the same as the ratio of the sum of the surface areas 102 and 104 of the rod ends of the pistons 64 and 66 to the sum of the surface areas 106 and 108 on the head end of the pistons 64 and 66. Since the areas 102 and 104 are equal and the areas 106 and 108 are equal, the ratio

of the surface area 94 to the surface area 96 of the piston 74 is the same as the ratio of the surface area 102 to the surface area 106 and is also the same as the ratio of the surface area 104 to the surface area 108. By equalizing the area ratios in this manner, accurate sensing of the overturning moment is promoted.

A dampening orifice or restriction 110 is advantageously provided in the line 82 which conducts the relatively high fluid pressure from the rod end chambers 54 and 56 of the tilt motor 22. The orifice 110 dampens transient pressure fluctuations due to the fluctuating load conditions on the fork 14.

The tilt motor assembly 22 includes two piston cylinder assemblies. Due to unequal loading conditions, one of the piston and cylinder assemblies can be subjected to a higher loading than the other piston and cylinder assembly. To provide for the communication of the fluid pressure to the detector assembly from the rod end chamber 54 or 56 in which the fluid pressure is the highest, a shuttle valve arrangement 114 is provided between the two rod end chambers 54 and 56. The shuttle valve arrangement 114 includes a pair of check valves 116 and 118. When the fluid pressure in the chamber 54 is greater than the fluid pressure in the chamber 56, the check valve 116 is open and the check valve 118 is closed. Similarly, when the fluid pressure in the chamber 56 is greater than the fluid pressure in the chamber 54, the check valve 118 is opened and the check valve 116 is closed. If desired the piston cylinder assemblies of the tilt motor assembly 22 could be constructed as disclosed in United States Patent No. 3,850,080 or in United States Patent No. 3,898,915.

A second shuttle valve arrangement 122 is provided in association with the head end chambers 58 and 60. The shuttle valve arrangement 122 includes two check valves 124 and 126. When the fluid pressure in the head end chamber 58 is greater than the fluid pressure in the head end chamber 60, the check valve 124 is open and the check valve 126 is closed. Similarly, when the pressure in the head end chamber 60 is greater than the pressure in the head end chamber 58, the check valve 126 is open and the check valve 124 is closed.

The pump 32 is driven by a continuously operating engine which is disposed on the lift truck 10. When the fluid pressure output from the pump 32 is not being utilized to operate either the lift motor 18 or the tilt motor assembly 22, the displacement of the pump is reduced in order to reduce the load on the engine and to promote efficient operation of the lift truck. Thus, when the tilt motor control valve 28 and the lift motor

control valve 38 are in their closed positions (illustrated in Fig. 3) blocking fluid flow to and from the associated motor assemblies, a pressure compensator control system 130 is activated to operate a fluid motor 132 against the influence of a biasing spring 134 and reduce the displacement of the pump 32.

The compensator control system 130 includes a fluid pressure actuated valve 138 having an operating or end chamber 140 connected with the main supply line 142 from the pump 32. The fluid pressure in the chamber 140 urges a valve spool 146 toward the left (as viewed in Fig. 3). Leftward movement of the valve spool 146 is resisted under the combined influence of a biasing spring 148 and fluid pressure conducted through an orifice 150 to a left pressure chamber 151 which is exposed to the end of the valve spool 146. The left pressure chamber 151 is connected with a drain or reservoir through the orifice 150, a second orifice 152, and a conduit 154.

When the control valves 28 and 38 are in the closed condition illustrated in Fig. 3, the fluid pressure applied to the left chamber 151 is equal to reservoir or tank pressure. Therefore, when the fluid pressure in the line 142 reaches a predetermined standby pressure sufficient to overcome the influence of the biasing spring 148, the valve spool 146 is shifted toward the left (as viewed in Fig. 3). This connects a conduit 158 with the fluid motor 132 through a passage 160 to thereby port the fluid pressure output of the pump 32 directly to the fluid motor 132. This fluid pressure causes a piston 164 in the fluid motor 132 to be moved toward the right (as viewed in Fig. 3) to thereby move the actuator member 52 and effect a decrease in the displacement of the pump 32.

When one of the control valves 28 or 38 is actuated, the fluid pressure which is conducted to the left end (as viewed in Fig. 3) of the valve spool 146 is increased to press the valve spool toward the right with a pressure force which varies as a function of variations in the load. If the load is relatively light and the actuated valve 28 or 38 is only partially opened, the pressure drop through the valve is relatively high. This results in only a slight increase in the fluid pressure in the chamber 151 allowing the pressure in the chamber 140 to actuate the valve 138 and effect operation of the fluid motor 132 to deswash the pump. However, as the valve 28 or 38 is fully actuated, the pressure drop across the actuated valve 28 or 30 decreases and an increased pressure is transmitted to the chamber 151. As the pressure transmitted to the chamber 151 increases relative to pressure in chamber 140, the pump 32 is upswashed.

Assuming that the control valve 28 is operated to port fluid under pressure through the passage 30 to the tilt motor assembly 22 when it is in a heavily loaded condition, high pressure fluid is also ported by an internal passage 172 to a conduit 174 which is connected through a check valve 176 in a conduit 180 with the restriction 150 and the left pressure chamber 151. Since the tilt motor assembly is heavily loaded, there is a relatively small pressure drop across the valve 28 and fluid pressure conducted to the chamber 151 is substantially equal to the fluid pressure in the supply conduit 142. Therefore, the fluid pressure in the chamber 140 is ineffective to move the valve spool 146 against the combined influence of the biasing spring 148 and the fluid pressure applied against the left (as viewed in Fig. 3) end of the valve spool. Since the conduit 180 is connected with drain through the orifice 152, as soon as the tilt motor control valve 28 is moved back to the closed position illustrated in Fig. 3, the pressure in the fluid conduit 180 is reduced and the valve spool 146 can again be shifted under the influence of fluid pressure in the chamber 140.

It should be understood that if the tilt motor assembly 22 is lightly loaded, and if valve 28 is partially opened, there is a substantial pressure drop across the valve 28. The fluid pressure ported to the fluid conduit 174 is less than the fluid pressure in the conduit 142. Therefore, the pressure conducted to the chamber 151 can be overcome by the fluid pressure in the chamber 140 and pump 32 deswashed.

When the tilt motor control valve 28 is operated toward the left (as viewed in Fig. 3) to port fluid pressure through the passage 34 to the rod end chambers 54 and 56 of the tilt motor assembly 22, an internal passage 188 of the valve ports fluid pressure from the rod end chambers 54 and 56 to the conduit 174. The conduit 174 is connected in fluid communication with the left end pressure chamber 151. Therefore, the fluid pressure in the rod end chambers 54 and 56 is utilized to bias the valve spool 146 towards its right hand position in Fig. 3.

The control valve 38 of the lift or hoist motor 18 is also effective to port fluid to the conduit 180 leading to the left end pressure chamber 151 of the compensator valve 146. When the valve 38 is shifted toward the right (as viewed in Fig. 3) to port fluid under pressure to the head end of the hoist motor 18, an internal passage 192 in the hoist control valve 38 ports fluid under pressure to the conduit 18. Similarly, upon operation of the hoist motor control valve 38 to the left, the head end of the hoist motor 18 is connected with drain and the conduit 180

is connected with fluid under pressure via passage 194.

It is contemplated that during operation of the vehicle 10 it may be desirable to either increase or decrease the extent to which the mast 12 is tilted when the load carriage or fork 14 is in a fully lowered position even though the vehicle is being subjected to an excessive overturning moment. To enable the inclination or tilt of the mast 12 to be varied under these conditions, an override valve 200 connected with the conduit 82 is operable to render the detector assembly 50 ineffective to reduce the displacement of the pump 32 when the carriage 14 is in a lowered position. Therefore, when the carriage 14 is lowered, the tilt motor assembly 22 can be operated to vary the extent to which the mast 12 is tilted.

When the carriage 14 is in a raised position, the override valve assembly 200 is retained in an open condition (shown in Fig. 3) under the influence of fluid pressure conducted through a conduit 202 from the head end portion of a hoist motor cylinder 18. This fluid pressure urges a valve spool 210 toward the left (as viewed in Fig. 3) against the influence of a biasing spring 212. When the valve assembly 200 is in the open position (illustrated in Fig. 3), a passage 216 conducts fluid pressure from the tilt motor assembly 22 to the detector assembly 50. Of course, this enables the detector assembly 50 to reduce the displacement of the pump 32 upon the application of excessive overturning moments to the vehicle 10.

When the hoist motor assembly 18 is fully retracted, the fluid pressure in the head end of the hoist motor cylinder 18 is relatively low. This relatively low fluid pressure is ineffective to overcome the influence of the biasing spring 212 so that the valve spool 210 is moved toward the right (as viewed in Fig. 3) to an actuated condition in which the transmission of fluid pressure from the tilt motor assembly 22 to the detector assembly 50 is blocked. In addition, a passage 220 in the valve spool 210 is effective to connect the chamber 76 with drain through a conduit 222. Of course, this renders the detector assembly 50 ineffective to reduce this displacement of the pump 32. Therefore, activation of the tilt valve 28 effects operation of the tilt motor assembly 22 to vary the extent to which the mast 12 is tilted even though the vehicle 10 is being subjected to an excessive overturning moment.

It is also contemplated that under certain operating conditions it may be desirable to decrease the extent to which the mast 12 is tilted when the vehicle 10 is being subjected to an excessive overturning moment. This is accomplished by effecting operation of the

tilt motor assembly 22 to swing the mast 12 in a counterclockwise direction from the tilted position shown in Fig. 2 to the upright position shown in Fig. 1.

To enable the tilt motor assembly 22 to be operated to move the mast 12 from a tilted position to a more rearward tilted position upon application of excessive overturning moment to the vehicle 10, a valve assembly 230 is operable from the open position of Fig. 3 to an actuated position in which the transmission of a pressure signal from the tilt motor assembly 22 to the detector assembly 50 is blocked. When the valve assembly 230 is in the actuated position, an internal passage 232 connects the detector assembly 50 with drain so that the detector assembly is ineffective to vary the displacement of the pump 32. The valve assembly 230 includes a valve spool 234 which is moved toward the right (as viewed in Fig. 3) from the illustrated open position to a position in which the detector assembly 50 is connected with drain through a conduit 236. The valve spool 234 is moved from the open position to the actuated position upon operation of the tilt control valve 28 to the reverse actuated position. In the specific embodiment of the invention illustrated in the drawings, upon movement of the tilt valve 28 to a reverse actuated position, a limit switch 240 is actuated to effect operation of a solenoid 242 to shift the valve spool 234 in a known manner against the influence of a biasing spring 244.

Although the two valve assemblies 200 and 230 have been shown in association with the tilt motor assembly 22 and the hoist motor assembly 18, it is contemplated that either one of the two valve assemblies could be utilized alone without the other valve assembly. For example, only the valve assembly 200 could be provided to enable the tilt motor assembly 22 to be operated upon the application of an excessive overturning moment to the vehicle 10 only when the load fork or carriage 14 is in the lowered position. Similarly, it is contemplated that only the valve assembly 230 could be utilized if it was anticipated that the vehicle 10 would encounter operating conditions in which it would be desirable to move the mast 12 from a forward tilted position to the upright position upon the application of excessive overturning moment to the vehicle.

A second embodiment of the invention is illustrated in Fig. 4 in association with a constant pressure control system. Since the embodiment of the invention illustrated in Figs. 1—3, similar numerals will be utilized to designate similar components. However, the suffix letter "a" will be added to the numerals associated with Fig. 4 in order to avoid confusion.

Operation of a tilt motor assembly 22a under the influence of fluid from a variable displacement pump 32a is controlled by a tilt motor control valve 28a. A detector assembly 50a is connected with rod end chambers 54a and 56a in the tilt motor assembly 22a by a conduit 82a. The detector assembly 50a is also connected with the head end chamber 58a and 60a by a conduit 84a. The detector assembly 50a includes a fixed cylinder 72a which cooperates with a movable piston 74a to move an actuator member 52a to reduce the displacement of the pump 32a when the overturning moment applied to the associated vehicle exceeds a predetermined value. The detector assembly 50a cooperates with the tilt motor assembly 22a in the same manner as previously described in connection with the embodiment of the invention disclosed in Fig. 3 and will not be further described herein to avoid prolixity of description.

A pressure compensator system 130a is effective to maintain a predetermined operating pressure in a main supply line 142a from the pump 32a. When the pressure in the supply line 142a exceeds a predetermined operating pressure, fluid pressure in a chamber 140a shifts the valve spool 146a toward the left (as viewed in Fig. 4) against the influence of a biasing spring 148a and fluid pressure in an operating chamber 151a. When the valve spool 146a is shifted toward the left (as viewed in Fig. 4), high pressure fluid from the conduit 142a actuates a fluid motor 132a to move the actuator member 52a to reduce the displacement of the pump 32a. It should be noted that the fluid pressure which is present in the conduit 142a when the valve spool 146a is shifted toward the left is relatively high since this fluid pressure must be sufficient to operate the tilt motor 22a. Therefore, the pressure compensator system 130a is effective to maintain a predetermined operating pressure in the conduit 142a.

After the fluid motor 132a has been operated to reduce the fluid pressure in the conduit 142a to a predetermined operating pressure, the valve spool 146a is returned to the unactuated condition illustrated in Fig. 4. This is accomplished under the influence of fluid pressure conducted from the fluid motor 132a to the pressure chamber 151a through a conduit 212. When this happens the fluid motor 132a is exhausted to drain and the actuator member 52a is returned to its maximum displacement condition under the influence of a biasing spring.

In view of the foregoing description, it can be seen that the detector assembly 50 is effective to prevent the application of excessive overturning movements to the vehicle 10 by reducing the displacement of the pump 32. The detector assembly includes a pair

of pressure chambers which are connected in fluid communication with the head and rod end operating chambers in the tilt motor assembly 22. Upon the application of an overturning moment in excess of a predetermined moment, a relatively large fluid pressure in the rod end chambers 54 and 56 is communicated to the pressure chamber 76 in the detector 50 and is effective to move the piston 74 against the biasing spring 88 to reduce the displacement of the pump 32 to a zero flow condition. In addition, a pressure compensator system 130 is associated with the pump 32 to effect a reduction in the displacement of the pump when it is not being utilized to operate the tilt control motor 22 or the hoist motor 18 to thereby reduce the load on a motor which is utilized to drive the pump 32.

WHAT WE CLAIM IS:—

1. A vehicle for use in moving a load, said vehicle comprising support means for supporting a load, fluid motor means for moving said support means in such a manner that the load subjects the vehicle to an increasing moment which tends to overturn the vehicle, variable displacement pump means for supplying fluid to said motor means, actuator means for varying the displacement of said pump means, and detector means for detecting the overturning moment to which the vehicle is subjected and for effecting operation of said actuator means to reduce the displacement of said pump means in response to the detection of an overturning moment of a value in excess of a predetermined overturning moment.

2. A vehicle as set forth in claim 1 wherein said support means includes an upstanding mast and a load engaging carriage connected with said mast, said motor means including a tilt motor connected with said mast and operable to change the angle of inclination of said mast relative to a vehicle support surface, said detector means being operable to detect the overturning moment applied to said vehicle as a result of operation of said tilt motor.

3. A vehicle as set forth in claim 2 wherein said tilt motor includes a cylinder defining a chamber and a piston disposed within said chamber, said piston being effective to divide said chamber into first and second end portions, and said detector means includes means for comparing the fluid pressure in one of said end portions of said chamber relative to the fluid pressure in the other of said end portions of said chamber to thereby detect the overturning moment applied to the vehicle.

4. A vehicle as set forth in claim 3 wherein said detector means includes a second cylinder defining a second chamber, a second piston disposed in said second

chamber, said second piston being effective to divide said second chamber into first and second end portions, first conduit means connecting said first end portion of said chamber in said tilt motor in fluid communication with said first end portion of said second chamber, second conduit means for connecting said second end portion of said chamber in said tilt motor in fluid communication with said second end portion of said second chamber to thereby apply a pressure differential across said second piston equal to the pressure differential across said piston in said tilt motor, and means for effecting operation of said actuator means in response to relative movement between said second piston and cylinder under the influence of the pressure differential across said second piston.

5. A vehicle as set forth in claim 4 wherein said detector means further includes biasing means for retarding relative movement between said second piston and cylinder to prevent operation of said actuator means until the predetermined overturning moment is present.

6. A vehicle as set forth in claim 4 wherein said piston in said tilt motor has a head end surface exposed to the fluid pressure in said first end portion of said chamber in said tilt motor and a rod end surface exposed to the fluid pressure in said second end portion of said chamber in said tilt motor, said rod end surface having an area which is smaller than the area of said head end surface, said second piston having a head end surface exposed to the fluid pressure in said first end portion of said second chamber and a rod end surface exposed to the fluid pressure in said second end portion, said rod and head end surface areas of said tilt motor having the same ratio to each other as said rod and head end areas of said second piston.

7. A vehicle as set forth in claim 1 further including valve means operable between a first condition blocking fluid flow from said pump means to said motor means and a second condition enabling fluid to flow from said pump means to said motor means, and compensator means for detecting when the fluid pressure output of said pump means is greater than a predetermined pressure when said valve means is in said first condition and for effecting operation of said actuator means to reduce the displacement of said pump means in response to detection of a fluid pressure output which is greater than the predetermined pressure when said valve means is in said first condition.

8. A vehicle as set forth in claim 7 further including means for rendering said compensator means ineffective to effect operation of said actuator means when the fluid pressure output of said pump means is

greater than the predetermined pressure and said valve means is in said second condition to enable said pump means to supply fluid to said motor means at a pressure which is greater than the predetermined pressure when said valve means is in said second condition.

9. A vehicle as set forth in claim 1 wherein said motor means includes first and second piston and cylinder assemblies having first and second operating chambers, said detector means including detector chamber means for receiving fluid, conduit means for conducting fluid pressure to said detector chamber means, and valve means for porting fluid pressure to said conduit means from the one of said operating chambers containing fluid at higher pressure.

10. A vehicle as set forth in claim 1 further including means for detecting when said motor means is in a predetermined operating condition and for rendering said detector means ineffective to reduce the displacement of said pump means when said motor is in the predetermined operating condition.

11. A vehicle as set forth in claim 1 wherein said support means includes an upstanding mast and a load engaging carriage connected with said mast, said motor means including a tilt motor connected with said mast and operable in a first direction to decrease the angle of inclination of the mast relative to a vehicle support surface and operable in a second direction to increase the angle of inclination of the mast relative to the vehicle support surface, and means for rendering said detector means ineffective to reduce the displacement of said pump means during operation of said motor means in said second direction.

12. A vehicle as set forth in claim 1 wherein said support means includes an upstanding mast and a load engaging carriage connected with and movable along said mast, said motor means including a hoist motor operable to move said carriage along said mast between a lowered position in which said carriage is disposed adjacent to a lower end portion of said mast and a raised position in which said carriage is disposed adjacent to an upper end portion of said mast, and means for rendering said detector means ineffective to reduce the displacement of said pump means when said carriage is in the lowered position.

13. A vehicle comprising a base, an upstanding mast connected with said base, load engaging means connected with said mast for engaging a load, tilt motor means for moving said mast and load engaging means relative to said base in such a manner as to vary an overturning moment to which said vehicle is subjected by a load engaged by said load engaging means, said tilt motor

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means including a piston and cylinder defining first and second chamber end portions, variable displacement pump means for supplying fluid under pressure to said cylinder of said motor means, said tilt motor means including means for subjecting fluid in one of said chamber end portions to forces which vary as a function of the overturning moment to which the vehicle is subjected and as a function of the fluid pressure in the other chamber end portion, actuator means operable to vary the displacement of said pump means, and comparator means for comparing the fluid pressures in said first and second chamber end portions and effecting operation of said actuator means to reduce the displacement of said pump means when the fluid pressure in said one chamber end portion exceeds the fluid pressure in said other chamber end portion by a predetermined amount.

14. A vehicle as set forth in claim 13 wherein said comparator means includes a piston and cylinder which defines third and fourth chamber end portions, first conduit means for conducting fluid pressure from said first chamber end portion to said third chamber end portion and second conduit means for conducting fluid pressure from said second chamber end portion to said fourth chamber end portion, the piston and cylinder of said comparator means being movable relative to each other under the influence of the fluid pressure in said fourth chamber end portion and biasing means for retarding relative movement between said piston and cylinder of said comparator means.

15. A vehicle as set forth in claim 14 further including restrictor means for restricting fluid flow in said second conduit means to retard transient fluctuations in the fluid pressure in said fourth chamber end portion.

16. A vehicle as set forth in claim 13 further including lift motor means for raising and lowering said load engaging means relative to said base.

17. A vehicle as set forth in claim 13 further including valve means for controlling

the flow of fluid from said pump means to said motor means, said valve means being operable between a closed condition blocking fluid flow to said motor means and an open condition enabling fluid to flow to said motor means, and means for effecting operation of said actuator means to reduce the displacement of said pump means when said valve means is in the closed condition.

18. A vehicle as set forth in claim 13 wherein said tilt motor means is operable in a first direction to move said mast and load engaging means in such a manner as to increase the overturning movement to which said vehicle is subjected by the load and is operable in a second direction to move said mast and load engaging means in such a manner as to decrease the overturning moment to which said vehicle is subjected by the load, and means for preventing operation of said actuator means to reduce the displacement of said pump means when said motor means is being operated in the second direction and the fluid pressure in said one chamber end portion exceeds the fluid pressure in said other chamber end portion by the predetermined amount.

19. A vehicle as set forth in claim 13 further including lift motor means for raising said load engaging means along said mast between a lowered position adjacent to a lower end portion of said mast and a raised position adjacent to an upper end portion of said mast, and means for preventing operation of said actuator means to reduce the displacement of said pump means when said load engaging means is in the lowered position and the fluid pressure in said one chamber end portion exceeds the fluid pressure in said other chamber end portion by the predetermined amount.

20. A vehicle substantially as either one of the embodiments hereinbefore described with reference to, and as shown in, the accompanying drawings.

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